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Research Document 2006/050 | **Document de recherche 2006/050**

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Update on investigations of bowhead whale (*Balaena mysticetus*) movements in the eastern Arctic, 2003-2005, based on satellite-linked telemetry

Mise à jour des études sur les déplacements des baleines boréales (*Balaena mysticetus*) dans l'est de l'Arctique, de 2003 à 2005, grâce à la télémétrie par satellite

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ISSN 1499-3848 (Printed / Imprimé)
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ABSTRACT

Using satellite-linked telemetry, studies of bowhead whale movements in Canada were conducted in northern Foxe Basin from 2001 to 2003 and in Cumberland Sound in 2004 and 2005. Four whales were tagged in 2001, but all provided data for <1 wk. Over the next four years, 28 bowhead whales were tagged in northern Foxe Basin (n=16) and Cumberland Sound (n=12), of which 9 provided no data, 6 tags transmitted for periods of up to one month, 8 for one to two months, 3 for two to three months, one for 3.5 months and one for about seven months. Of 13 tags deployed in northern Foxe Basin that provided data for ≥18 days, eight moved through Fury and Hecla Strait and ranged throughout Gulf of Boothia and Prince Regent Inlet. The remaining five whales made mostly local movements. Of 4 whales tagged in Cumberland Sound that provided data for ≥26 days, all moved out of Cumberland Sound. Three of these whales traveled to Prince Regent Inlet, one of which made a nearly complete circumnavigation of Baffin Island. The latter took up winter residency in Hudson Strait. Six females accompanied by calves were among those whales tagged in Foxe Basin, and two moved into Prince Regent Inlet. Both adult males and juveniles were among those tagged in Cumberland Sound and that moved to Prince Regent Inlet. Combined with tracking results of Greenland whales, the findings indicate that bowhead whales are wide ranging and whales from both Foxe Basin and Baffin Bay regions share common ranges in summer as well as winter. Whales tagged in all localities exhibited varying travel routes. Common use of wintering ranges suggests that there is potential for significant genetic exchange between the various components of the eastern Arctic population.

RÉSUMÉ

La télémétrie par satellite a été utilisée pour étudier les déplacements des baleines boréales au Canada, dans le nord du bassin Foxe, entre 2001 et 2003, et dans la baie Cumberland, en 2004 et en 2005. Quatre baleines ont été marquées en 2001, mais toutes n'ont transmis des données que pendant <1 semaine. Au cours des quatre années suivantes, 28 baleines boréales ont été munies d'émetteurs dans le nord du bassin Foxe (n=16) et dans la baie Cumberland (n=12). Neuf de ces émetteurs n'ont fourni aucune donnée, six ont pu transmettre pendant jusqu'à un mois, huit pendant un à deux mois, trois pendant deux à trois mois, un pendant 3,5 mois et un autre pendant environ sept mois. Sur les 13 baleines munies d'émetteurs déployés dans le bassin Foxe qui ont transmis des données pendant ≥18 jours, huit ont emprunté le détroit de Fury et Hecla et se sont déplacées dans le golfe de Boothia et l'inlet Prince Regent. Les déplacements des cinq autres baleines ont été plutôt localisés. Les quatre baleines marquées dans la baie Cumberland qui ont transmis des données pendant ≥26 jours ont toutes quitté la baie. Trois d'entre elles ont voyagé jusqu'à l'inlet Prince Regent dont l'une d'elles a effectué le tour presque complet de l'île de Baffin. La dernière a passé l'hiver dans le détroit d'Hudson. Six femelles accompagnées de jeunes étaient de ceux marqués dans le bassin Fox, et deux se sont déplacées sur l'inlet Prince Regent. Des mâles adultes et des jeunes faisaient partie des baleines marquées dans la baie Cumberland qui se sont rendues jusqu'à l'inlet Prince Regent. Ajoutées aux résultats du suivi des baleines du Groenland, ces données permettent de conclure que les baleines boréales sont très mobiles, et que les baleines des régions du bassin Foxe et de la baie Baffin ont des aires communes en été et en hiver. Les baleines marquées à tous les endroits ont emprunté des routes différentes. Le partage des aires hivernales indique qu'il pourrait y avoir d'importants échanges génétiques entre les diverses composantes de la population de l'est de l'Arctique.

INTRODUCTION

Evidence indicates that the migrations of the bowhead whales are closely linked to ice conditions and have likely tracked the advance and retreat of the northern pack ice edge for millennia (Eschricht 1866, Moore and Reeves 1993, Dyke *et al.* 1996). Whalers in the eastern Canadian Arctic and Greenland were well acquainted with the seasonal movements of these animals (reviewed by Reeves *et al.* 1983 and Ross 1974). Based on their accounts, Southwell (1898) developed the first comprehensive theory of bowhead migrations for the region. Recently, the development and application of satellite-linked telemetry to the studies of baleen whales (Heide Jørgensen *et al.* 2001) has begun to provide valuable insight into the present distribution and movements of the bowhead whales of the eastern Canadian Arctic and west Greenland (Heide Jørgensen *et al.* 2003, 2006). Application of this technology is also important in addressing issues of importance to managers, in particular, the discreteness of stocks.

In Canada, two populations of bowhead whales were designated by COSEWIC[1] in the 1980s, identified as the Eastern and Western Arctic populations (COSEWIC 2003). In 2005, COSEWIC reviewed the status of bowhead whales in Canada and on the basis of preliminary genetic evidence (Postma *et al.* 2005), separated them into three populations: i) Bering-Chucki-Beaufort, ii) Hudson Bay-Foxe Basin, and iii) Davis Strait-Baffin Bay population (COSEWIC 2005). Until recently, there has been little other evidence to evaluate the hypotheses regarding the degree of mixing or isolation of these two presumed eastern Arctic populations.

Under the Nunavut Land Claims Agreement, Nunavut Inuit are legally entitled to a subsistence bowhead hunt (DIAND 1993), subject to legitimate conservation concerns. Due to a need to provide a scientific basis for management recommendations, DFO initiated studies of bowhead whales in the eastern Canadian Arctic to evaluate bowhead whale abundance, stock discreteness, movements and stock range. A study of bowhead whale movements and stock range, begun in 2001, was intended to address the question of the northern limit of Foxe Basin bowhead whales and the related question of stock identity in the Gulf of Boothia region. Kugaaruk, a small community located west of Fury and Hecla Strait (Figure 1), would be hunting from the Baffin Bay/Davis Strait stock if the current two-stock hypothesis is correct but could be hunting from the Hudson Bay/Foxe Basin stock if whales from Foxe Basin move through Fury and Hecla Strait. This study of movements included tagging efforts in Foxe Basin and Cumberland Sound. Concurrently, studies of bowhead whale movements were being conducted of bowhead whales found in the waters of west Greenland in April. This update describes the results of satellite-linked telemetry studies in these areas, and discusses some of the implications of these findings.

[1] Committee on the Status of Endangered Wildlife in Canada

METHODS

Study Area and Dates of Tagging

Studies of bowhead whale movements in Canada were conducted from 2001 to 2005 in northern Foxe Basin and in Cumberland Sound (Figure 1). In northern Foxe Basin, tagging efforts were conducted between July 4th and 18th in 2001 to 2003. In early July of all years, ice conditions in northern Foxe Basin consisted of a floe edge with landfast ice in the extreme northern reaches of Foxe Basin and Fury and Hecla Strait, and a mix of open water and pack ice to the south of Igloolik. Breakup occurred between July 11th and 13th (± 1 day) in all years.

In 2004, tagging efforts took place in Cumberland Sound between May 26th and May 29th. A mix of open water, shore ice and pack ice characterized the sound during this period. Pack ice closed up the sound in late May 2004 and prohibited further tagging efforts. In 2005, tagging work in Cumberland Sound was conducted between July 8th and July 16th. The conditions at this time were dominated by open water.

Description of Tags and Configurations

The movements of whales were documented with satellite-linked telemetry. The satellite-linked instruments used in this study were of two types: SPOT (position-only) tags and SDR (dive-recording) tags. SPOT tags were manufactured by Wildlife Computers (Redmond, Washington). The SDR transmitter was a model "SDR T-16", supplied by Telonics and modified by Wildlife Computers. Both the SPOT and SDR tag transmitters provided information on date, time, and location of the whale, as well as information on the quality of location estimates. The SDR tags additionally provided binned information on dives, which are not presented in this paper. Tag configurations and tagging methods used in this study were initially developed by Danish researchers for large baleen whales and described in Heide Jørgensen *et al.* (2001, 2003). Changes to tag design, configuration and tagging techniques were made during the period of studies in Canada and Greenland.

Tag transmitters were deployed in four different configurations: i) as "can" tags, in which the transmitter was housed in a an epoxy/steel cylinder (~100 mm long × 32 mm diameter) with an anchoring device affixed directly to the bottom of the tag; ii) as "mini-can" tags, in which the transmitter was housed in a smaller epoxy/steel cylinder (45 mm long × 32 mm diameter) with an anchoring device affixed directly to the bottom of the tag; iii) as tethered buoyant "float" tags, in which the transmitters were housed in a torpedo-shaped float and coupled to the anchor by means of a wire tether; and iv) as "implant" tags, in which the transmitters were housed in stainless steel cylinders (170 mm long x 20 mm diameter) with a bottom mounted anchor. The first three tag configurations were external to the whales, affixed with an anchor implanted in the blubber layer. The anchor was either a 25-30 cm long stainless steel rod with flexible barbs, or a stainless steel harpoon head. The

"implant" tag was implanted in the blubber layer along with a bottom-mounted anchor (~25 cm long stainless steel rod with barbs), with 5-10 cm of the tag as well as the antenna sticking out.

Tagging Methods and Gender/Age Class Determination

Whales were tagged using an 8 m hand-held fibreglass pole, counterweighted to provide a reach of about 5 m from the bow of a small (8 m) boat. Prior to tagging, the tag anchor was sterilized with an antiseptic. An estimate of whale body length was obtained during pursuit by relative comparison of whale body length to the known length of the boat. On a successful approach, the tagger pushed the anchor into the blubber layer, as high on the back of the whale as possible. During most tag deployments, a skin biopsy was obtained using a small biopsy instrument attached alongside the end of the tagging pole. This device removed some skin when the tag anchor was pushed into the whale. Biopsy samples were also taken by using a crossbow with arrows fitted with biopsy tips. Samples were stored in DMSO until transported to the laboratory.

To determine the gender of tagged animals, DNA was extracted from the skin biopsy samples using DNeasy tissue extraction kits (Qiagen). The sex of each of the animal sampled was then determined using polymerase chain reaction (Bérubé and Palsbøll 1996). Broad age classes (calf, juvenile, adult) were determined for tagged whales using estimated body lengths and gender specific length-at-age information (Koski *et al.* 1993, O'Hara *et al.* 2002). Calves were defined as any bowhead whales with body lengths < 7.5 m, juvenile males as 7.5 m to 12 m, juvenile females as 7.5 m to 13 m, adult males as > 13 m, and adult females as > 13.5 m.

Analysis of Argos Data

The raw Argos data was filtered to remove redundant and erroneous location data. Bowhead whale locations were mapped using daily averages of all quality locations.

In some cases, the tethered float tags continued to provide positions for a period after they were determined to have come off the whales. The date of attachment failure was deduced by examining the number and quality of ARGOS positions each day. The detachment date was associated with an increase in the number of good quality positions and little movement of the tag position.

RESULTS

Tag Deployments and Whale Gender/Age Designation

In northern Foxe Basin, four can tags were initially deployed in 2001, but all four failed to provide any data. Thirteen tags were deployed in northern Foxe Basin in 2002 and 2003 prior to breakup along a floe edge and in the open waters between

Igloolik and Jens Munk Island. Three tags were additionally deployed post-breakup (after July 12th) in eastern Fury and Hecla Strait in 2003. SPOT tags were used exclusively in 2002 and were configured either as tethered float tags (n=5) or can tags (n=2). In 2003, all tags were configured as tethered float tags, but consisted of a combination of SPOT (n=5) and SDR (n=4) tags.

Of the sixteen tags deployed in northern Foxe Basin, 13 provided data for 18 days or more, up to a maximum of 121 days. Mean tag life, not including those active for < 1 week, was 51.8 days (n=13). Based on gender analysis and length estimation, most tagged whales were adult females (n=7), followed by juvenile females (n=5). and juvenile or adult males (n=3). Three cases of females that were estimated at 13 m were designated as adults rather than juvenile, because they were accompanied by calves. A total of six adult females were accompanied by calves. Three males estimated at 13 m could not be unambiguously designated as either juvenile or adult.

Three SPOT tags were deployed in Cumberland Sound in late May 2004. Two of the tags were mini-cans and one was an implant tag. Only the implant tag remained active after deployment, for a period of 42 days. This whale was identified as an adult male. The other two whales were an adult female and a male, either juvenile or adult.

In July 2005, nine SPOT tags were deployed in Cumberland Sound. Four were mini-cans and five were implants. Only three tags (1 mini-can, 2 implants) provided data for more than a few days, active for 26, 55 and 200+ days (mean = 40.5 days, n=3, one tag still active). Of the whales that were tagged, three were juvenile females, four were juvenile males, one was an adult female, and another was a juvenile of unknown gender. No calves were seen in Cumberland Sound in either 2004 or 2005.

Overall tag performance varied significantly. Of the 32 tags deployed between 2001 and 2005, 15 provided data for less than one week, 4 transmitted for periods between two weeks and one month, 8 for between one and two months, 3 for two to three months, 1 for three months and one for seven months.

Movements of Foxe Basin Bowhead Whales - 2002 and 2003

In July 2002, seven bowhead whales were tagged, for which the movements of four were documented for periods of more than one week (41-79 days), from July 5th to September 24th (Table 1). Of the four whales, three were adult females, and one was a juvenile male. Two of the adult females were accompanied by calves. Prior to mid-July, all four of these whales remained in northern Foxe Basin within about 50 km of the tagging area. One of these (#24641, adult female) remained south of the floe edge in the area between Igloolik Island and Rowley Island for the duration of its active tag life (July 5 to August 23). A female accompanied by a calf (#37227)

moved into the eastern portion of Fury and Hecla Strait briefly (on July 13) before moving back into northern Foxe Basin. After that, it remained within 50 km of the west shore of Foxe Basin, moving gradually south along Melville Peninsula to an area south of Hall Beach. The other female with calf (#37228) remained south of the floe edge and moved gradually south along Melville Peninsula until by September 11, this whale was near the coast of Vansittart Island, just north of Southampton Island (Figure 2a).

One tagged whale (#20685, juvenile male) moved through Fury and Hecla Strait into the Gulf of Boothia and Prince Regent Inlet in mid-July 2002. By mid-September, this bowhead had moved north into central Prince Regent Inlet (Figure 2a). The final signals were received in late September from the west side of Prince Regent Inlet, south of Bellot Strait.

In July 2003, nine whales were tagged, all of which transmitted data for more than two weeks, covering the period from July 5th to November 15th. Seven of the nine tagged bowhead whales (four juvenile females, two adult females and one male, either juvenile or adult) moved out of Foxe Basin through Fury and Hecla Strait. They moved through Fury and Hecla Strait between July 11th and July 23rd, completing the more than 100 km distance in 2-3 days. Six of these (20167, 21802, 24641, 26712, 37230, and 37280) ranged throughout much of Gulf of Boothia and Prince Regent Inlet during mid-July to mid-October, extending to the northern limit of Prince Regent Inlet (Figure 2b). After the first week of September, with only 3 tags active, three bowhead whales had moved into or near Lord Mayor Bay on the west side of the Gulf of Boothia. Finally, one remaining active tag (#37280; female with calf) moved back through Fury and Hecla Strait during October 13-14, eventually reaching the northeast coast of Southampton Island in early November.

Movements of the two whales that remained in Foxe Basin in 2003 were tracked from July 5 to August 27. Both of these whales (#20160 and #37231) were females accompanied by calves and made only local movements.

Overall, one of four (25%) whales passed through the strait in 2002 (excluding those with a tag lifespan < 7 days) while seven of nine (78%) did so in 2003. In total, eight of thirteen (62%) whales tagged in Foxe Basin (for a tag lifespan >7 days) moved west through Fury and Hecla Strait. There was no significant difference in tag lifespan between those whales that stayed in Foxe Basin (mean = 33.8 days, SD = 17.9, n = 6) and those that moved through Fury and Hecla Strait (mean = 59.5 days, SD = 33.4, n = 8) (Mann-Whitney, p=0.121)

The dates of passage through Fury and Hecla Strait were between July 11 and 23 and all transit times were less than 3 days. Of those whales that stayed in Foxe Basin (excluding those with a tag lifespan < 7 days), all were adult females (n=5), four of which were accompanied by calves). Of eight whales that moved into Gulf of Boothia and Prince Regent Inlet, there were two adult females with calves, four juvenile females, one juvenile male and one male of either juvenile or adult status.

Movements of Cumberland Sound Bowhead Whales - 2004 and 2005

The single reporting tag in 2004 documented the movement of an adult male out of Cumberland Sound, north along the east coast of Baffin Island, through Lancaster Sound and into Prince Regent Inlet (Figure 3a). The movement out of Cumberland Sound occurred in late June or early July. The whale moved through Lancaster Sound in mid-July, entering Prince Regent Inlet in the third week of July. This whale was in central Prince Regent Inlet off Bellot Strait when the tag stopped reporting.

Of the three whales in 2005 that provided location data for more than a few days, two were juvenile males and one was a juvenile of unknown gender (Table 1). All three whales moved out of Cumberland Sound by the third week of July. One whale (#3965) moved north along the east coast of Baffin Island to Home Bay (Figure 1, 3b) and remained in that vicinity until mid-August when the tag stopped reporting.

A second whale (#20167) also moved north along eastern Baffin Island in 2005. It remained near the east coast of Baffin Island in the vicinity of Isabella Bay until the second week of August. Further locations were not received until October 10th, when it was located in northern Foxe Basin. In mid-October, whale #20167 began movement south, remaining in the region of south-western Foxe Basin until the third week of November, then moving into Hudson Strait, where it continues to report as of January 2006 (Figure 3b).

The third whale (#20687) moved south out of Cumberland Sound around the third week of July 2005 and into Foxe Basin in early August. In mid-August it moved through Fury and Hecla Strait and south into Committee Bay. By the third week of August, this whale was in southern Prince Regent Inlet. In late August and early September, whale #20687 moved into Lord Mayor Bay in western Gulf of Boothia, where tag activity ended (Figure 3b).

DISCUSSION

General Seasonal Distribution and Migration Patterns

Historically, Roes Welcome Sound was the only known concentration area for bowhead whales in Hudson Bay and Foxe Basin and was the centre of whaling activity in the region (Ross 1974, Reeves *et al.* 1983). There are few published sightings of bowhead whales in Foxe Basin until the 1960s (Reeves *et al.* 1983), although archeological evidence suggests that bowhead whales were common there at one time (Brody 1976). Typically heavy ice conditions in northern Foxe Basin, which have been known to persist through the summer months (Smith and Rigby 1981), are thought to have made this area largely inaccessible during the whaling era (Ross 1974). Aerial surveys documented the presence of bowhead whales in

the area north of Igloolik Island during August 1996-1998 (Cosens *et al.* 1997, Cosens and Blouw 2003), corresponding roughly to the area where whales were tagged.

Four bowhead whales that were tagged and stayed in Foxe Basin were tracked up until at least the third week of August. The tracking data indicated that these whales restricted their movements to the west side of Foxe Basin during the summer, in the region between northern Foxe Basin and as far south as Southampton Island. Local knowledge suggests that whales arrive in northern Foxe Basin by passing directly north through Foxe Channel. After the ice breaks up, they spend time in Murray Maxwell Bay and many of the bays in western Foxe Basin (NWMB 2000, Solomon Qanatsiaq *pers. comm.*), consistent with the results of this study.

The findings of this study provide no indication one way or another that the region of Roes Welcome Sound is still an important summering area for bowhead whales. The bowhead whales in this area were thought to come from Hudson Strait and arrive at the south end of the sound in spring and move progressively northward as the season progressed, into Repulse Bay and associated smaller bays and channels north of Southampton Island such as Lyon Inlet, Gore Bay, and Frozen Strait (Ross 1974, Reeves *et al.* 1983). The movements of one whale tagged in Foxe Basin included the area near Lyon Inlet and Gore Bay, supporting Ross's (1974) suggestion that bowhead whales in this area might be whales that come from northern Foxe Basin. However, if whales arrive at Roes Welcome Sound in early spring directly from Hudson Strait and remain there during the summer as claimed by Ross (1974), they would not be represented by the whales tagged in northern Foxe Basin.

The results for whales tagged in Foxe Basin suggest that a significant component of the bowhead whales found in northern Foxe Basin (62% of tagged whales overall) move through Fury and Hecla Strait to summer in the Gulf of Boothia and Prince Regent Inlet. Sightings by local residents also indicate that bowhead can be seen in the strait during July (Solomon Qanatsiaq *pers. comm.*). Passage through the strait appears to occur fairly rapidly, over the course of a few days or less, and within two weeks of breakup. Once through the strait, the range of movements includes the area from Committee Bay to the northern extent of Prince Regent Inlet. The most predominant area of use in summer is central Prince Regent Inlet, southeast of Creswell Bay. In fall, a movement toward the western shore is demonstrated by tagged whales.

Bowhead whales tagged in west Greenland during roughly the same period as the work conducted in Canada demonstrate that these whales move across Baffin Bay into Canadian waters in June (Figure 4; Heide Jørgensen *et al.* 2003, 2006). Combined with unpublished data (Mads Peter Heide Jørgensen, *pers. comm.*), the results indicate that after some initial time spent off Lancaster Sound, some of these whales enter the Canadian Arctic archipelago in summer, moving as far as 95°W in Barrow Strait and into adjacent fiords, including Prince Regent Inlet (Figure 5).

Others remain along eastern Baffin Island during the summer and spend some of their time in Isabella Bay.

There were only a few bowhead whales tagged in Cumberland Sound with sufficient tag longevity to provide an indication of seasonal movements for whales from this region. With the small sample size, it is significant to note the divergence of travel routes used. These whales moved out of Cumberland Sound to the opposite side of Baffin Island using two routes, a northern route via Lancaster Sound, and a southern route via Hudson Strait and Foxe Channel. The movements of whales tagged in this area indicate that they use the same areas in Prince Regent Inlet and Foxe Basin as the whales tagged in Foxe Basin and Greenland.

The area of Resolution Island, southeast of Cumberland Sound, was known by whalers as the "south-west fishing". Although the whaling here was difficult due to weather and ice, whales could be found here from early April through June, and often, the whales taken here were large (Reeves *et al.* 1983). Our tagging work in this area was conducted in Cumberland Sound in July, so our observations and tagging of juvenile whales may be explained by the slight difference in timing and location. There is evidence from the western Arctic that juvenile bowhead whales prefer coastal areas (Moore and Reeves 1993).

Only five whales tagged in Canada or Greenland had tags with sufficient longevity to demonstrate fall movements and provide an indication of winter distribution. Two of these were tagged in Canada and three in Greenland. The Greenland whales all moved into Hudson Strait in mid-November. One of these was a whale that had been in Barrow Strait and the others were ones that spent the summer on the east side of Baffin Island (Heide Jørgensen *et al.* 2006). For whales tagged in Canada, the return migration from Prince Regent Inlet, including passage through Fury and Hecla Strait, began in October. One of these moved into Hudson Strait in late November, while the other one ended tag activity in November near the southeastern end of Southampton Island. The latter may have quit before documenting movement into Hudson Strait. The overall seasonal distribution of bowhead whales is depicted in Figure 6.

Movement through Fury and Hecla Strait

It had previously been thought that it might not be possible for appreciable numbers of whales to pass through Fury and Hecla Strait on an annual basis, due to the ice conditions in the region (Moore and Reeves 1993). The possibility of a spring movement into Gulf of Boothia from Foxe Basin via Fury and Hecla Strait was dismissed outright by Southwell (1898), who concluded that the breakup of ice in the narrow straits was typically too late for such a movement. Local Inuit knowledge at around that time provides support for this assessment, indicating that "ice was always late in leaving Fury and Hecla Strait" (Bernier 1911), typically opening in the month of September (Bernier 1909). The presence of bowhead whales in Prince

Regent Inlet and Gulf of Boothia was largely believed to be the sole result of whales entering the region from Baffin Bay via Lancaster Sound, not via Fury and Hecla Strait (Southwell 1898, Reeves *et al.* 1983). There was however speculation by some that whales might pass through the strait in certain seasons. Southwell (1898) was of the opinion, based on whalers accounts, that females and young animals used the strait during their fall movements south from the Gulf of Boothia.

It is not clear whether the movement through Fury and Hecla Strait is i) a regular occurrence, ii) a more recent occurrence due to climate warming and reduction in ice cover, or iii) a rare or variable event subject to normal variability in climate, allowing for periodic passage through the strait. There is some evidence that ice conditions have likely changed since the whaling era. Records of average ice conditions indicate that the opening of the strait now occurs earlier than that claimed by the Inuit of Bernier's time. The most recent 30-year average ice cover data for Fury and Hecla Strait indicates that ice of 10/10 persisted to a median date of July 23, thereafter decreasing to 9/10 and then 3/10 in the following two weeks (Canadian Ice Service 2002), much earlier than the September opening reported by Bernier. Examination of winter open-water refugia also suggests that open water in northern Foxe Basin has increased over the same period (Heide Jørgensen and Laidre 2004). That the extent of sea ice was greater during the period of early whaling makes sense, given that it took place during the Little Ice Age (~1600 to ~1850). Thus Southwell's (1898) strong conviction that bowhead whales were unable to move through Fury and Hecla Strait in spring during his era may be justified. Due to the size and location of this channel, Fury and Hecla Strait is likely to be subject to climatic fluctuations, alternately allowing and preventing travel through the strait over both short and long terms.

Movements by Specific Age/Reproductive Classes

Six females with calves were tagged in Foxe Basin, consistent with observations by Cosens and Blouw (2003) who suggest that Foxe Basin serves as a nursery area. Four stayed in Foxe Basin and two moved into Gulf of Boothia/Prince Regent Inlet. Those that moved out of Foxe Basin had twice the average tag longevity (74.5 days) of those that stayed in Foxe Basin (37.5 days), suggesting that there may have been some bias toward those that stayed in Foxe Basin (i.e. had the tags lasted longer, the whales may have demonstrated movement out of Foxe Basin). However, the sample size was insufficient to confirm a statistical difference. Local knowledge indicates that large bowhead whales with calves are regularly observed to reside in some of the bays of Foxe Basin such as Roche Bay (south of Hall Beach) during the summer (NWMB 2000, Solomon Qanatsiaq *pers. comm.*). There is also evidence for whales of different ages, including calves, present in the region of Roes Welcome Sound (Reeves and Cosens 2003).

None of the juveniles tagged in northern Foxe Basin (n = 5) stayed in Foxe Basin. All moved through Fury and Hecla Strait into Gulf of Boothia and Prince Regent Inlet. There were no adult males among the whales tagged in northern Foxe Basin.

Both juvenile and adult age classes of both genders were tagged in Cumberland Sound, although only records for an adult male, two juvenile males and a juvenile of unknown gender provided location data for any length of time. No females with calves were observed in Cumberland Sound. Although the sample was too small to provide much information about differences in age, gender, or reproductive class specific movements, both adult and juvenile males were among those that moved to Foxe Basin and Prince Regent Inlet. The individual that circumnavigated Baffin Island was a juvenile of unknown gender.

Southwell (1898) summarizes the accounts and beliefs of whalers who claimed that bowhead whales were segregated during the migration. He suggests that females with young migrated largely independently of the old males, moving north along eastern Baffin Island to Prince Regent Inlet and Gulf of Boothia, and returning via Furya and Hecla Strait. The route of old whales without young were suggested to move toward Greenland in early spring then across to northern Baffin Island waters and eventually to return along eastern Baffin Island in fall. Although his presentation is not completely consistent with our findings, there are some aspects of his description that appear to be supported. The whales tagged in Greenland were all ≥12 m (Heide Jørgensen *et al.* 2006), (suggesting that most were sexually mature) while those tagged in Foxe Basin and Cumberland Sound consisted mostly of juveniles and females with calves. Females with calves were commonly observed in northern Foxe Basin during this study, while calves are rarely seen along eastern Baffin Island in fall (Finley 1990). Age and reproductive class segregation is also supported by the results of aerial surveys in Foxe Basin, Gulf of Boothia and Prince Regent Inlet (Cosens and Blouw 1999, Cosens *et al.* 2006),

Local residents also provide evidence of age segregation. They indicate that small whales are the first to arrive in spring in northern Foxe Basin followed by larger whales a couple of weeks later (Solomon Qanatsiaq, *pers. comm.*).

Over-Wintering Areas

Most bowhead whales summering in Hudson Bay are thought to over-winter in northern Hudson Bay and western Hudson Strait (Reeves *et al.* 1983, Moore and Reeves 1993), although direct evidence is sparse. Reeves *et al.* (1983) thought it unlikely that a large component of the Hudson Bay summer population over-winters in northern Hudson Bay. Winter sightings of bowhead whales as far east as eastern Hudson Strait have been attributed to whales from Hudson Bay (Finley *et al.* 1982).

Over-wintering areas in Baffin Bay have been documented in the waters of west Greenland (Born and Heide Jørgensen 1983), which were also well known by

whalers (Eschricht 1866). Over-wintering areas in Baffin Bay are also thought to include the entire limit of pack ice between the mouth of Hudson Strait and the coast of Greenland (Reeves *et al.* 1983). However, few observations have been made and those available suggest that the distribution along the Baffin pack edge may be disjunct rather than continuous (McLaren and Davis 1982).

To date, the telemetry studies support the premise that Hudson Strait is an important wintering area. The tracks of whales tagged in Cumberland Sound and Greenland indicate that all whales with sufficient tag longevity over-winter in Hudson Strait. The documented range of movements in the wintering area of Hudson Strait extends from the eastern to western end of the strait. The whales tagged in Foxe Basin have not conclusively confirmed the use of Hudson Strait in winter (due to the limits of active tag life). The closest approach by bowhead whales tagged in northern Foxe Basin was the northeast coast of Southampton Island (~200 km from western Hudson Strait).

Although some sexual activity is known to occur in bowhead whales during most months of the year, distribution of whales during the winter months are of particular interest, since this is presumed to be the peak time for mating and thus for genetic exchange. Koski *et al.* (1993) suggest that conception likely occurs during a restricted period in late winter or spring.

Biases and Sources of Error

Tag longevity may introduce some bias in the interpretation of whale movements. Obviously the tags providing records for short periods are incomplete records of seasonal movements. This potential bias is evident most clearly for whales tagged in Cumberland Sound and Greenland. For these whales, those with the greatest tag longevity clearly provided the longest track records. It is unlikely that tags with short lifespan reflect a complete picture of seasonal movements.

Although there was no apparent statistical difference in tag longevity of northern Foxe Basin whales between those that stayed in Foxe Basin versus those that went through the strait, bias in the measure of the proportion of whales that moved out versus stayed in Foxe Basin may have gone undetected due to small sample size. When restricting the analysis of tracks to those whales whose tags functioned for more than 3 weeks, the proportion of whales that moved through the strait increases from 62% to 75% (8 of 12 tags).

CONCLUSIONS

Given a sufficient sample size representative of the population of interest, the use of satellite-linked telemetry provides a largely unbiased approach to documenting the seasonal distribution and movement patterns of animals. Despite a relatively small

sample in the studies reported here, and limited to whales tagged in three localities at specific times of the year, the findings provide a reasonable sampling of age, gender, and reproductive classes, and demonstrate clearly some of the extent of the range and the variability of bowhead whale movements in the eastern Canadian Arctic. It is likely that these results do not entirely document the complete range and patterns of movements of bowhead whales in the eastern Canadian Arctic, but they do provide considerable insight into their seasonal distribution and movement patterns.

The results clearly indicate that bowhead whales are wide ranging in their travels. To a large extent, whales that are observed in distant localities in spring ultimately share the same summering and/or wintering areas. Common use of summering and wintering ranges suggests that there is potential for significant genetic exchange between the various components of the eastern Arctic population. The conclusion that there is no evidence for distinct populations in the eastern Canadian Arctic is supported by recent genetic analysis (Postma *et al.* 2006).

The distinction in the bowhead scientific literature between biologically unique "populations", and "stocks", is not always clear. Implications that two or more biologically isolated populations may exist or were historically present are often tempered by the admission of uncertainty regarding the degree of mixing (Ross 1974, Mitchell and Reeves 1981, Mitchell and Reeves 1982, Reeves *et al.* 1983, Finley 1990, Reeves and Mitchell 1990). Some suggest that the recognition of two stocks is advisable for management purposes (Allen 1978, Reeves and Mitchell 1990). Although the results presented here provide no evidence of distinct populations, the recognition of separate stocks for management purposes may still be warranted given that there may be some degree of age and reproductive class segregation during parts of the year when hunting may occur.

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Table 1. Summary of information on satellite-linked tag deployments during Canadian studies of bowhead whales in 2001 to 2005. See text for descriptions of tag types and configurations. Note that four bowhead whales were tagged in 2001 (SPOT tags configured as "can" tags), but failed to provide any data. Location abbreviations defined as: FB = Foxe Basin; CS = Cumberland Sound.

Year (location)	Whale ID #	Tag type	Tag configuration	Gender and estimated length of whale[1]	Age class	Date tagged	Tag days
2002 (FB)	13280	SPOT	Float	male, 13 m	juv. or adult	05 July 02	5
	20685	SPOT	Float	male, 12 m	juv.	05 July 02	79
	24641	SPOT	Float	female, >15 m	adult	05 July 02	48
	27259	SPOT	Can	unkn., 12 m	juv.	08 July 02	0
	27260	SPOT	Can	female, 12 m	juv.	08 July 02	0
	37227	SPOT	Float	female*, 15 m	adult	11 July 02	41
	37228	SPOT	Float	female*, 14 m	adult	12 July 02	46
2003 (FB)	20160	SDR	Float	female*, 15 m	adult	05 July 03	18
	20167	SDR	Float	male, 13 m	juv. or adult	07 July 03	35
	21802	SDR	Float	female*, 13 m	adult	11 July 03	28
	24641	SPOT	Float	female, 11 m	juv.	08 July 03	71
	26712	SDR	Float	female, 12 m	juv.	18 July 03	19
	37229	SPOT	Float	female, 10 m	juv.	18 July 03	50
	37230	SPOT	Float	female, 11 m	juv.	10 July 03	73
	37231	SPOT	Float	female*, 13 m	adult	12 July 03	45
	37280	SPOT	Float	female*, 13 m	adult	18 July 03	121
2004 (CS)	3960	SPOT	Mini-can	male, 13 m	juv. or adult	27 May 04	0
	3962	SPOT	Mini-can	female, 14 m	adult	27 May 04	0
	20157	SPOT	Implant	male, 14 m	adult	27 May 04	42
2005 (CS)	3964	SPOT	Mini-can	male, 9 m	juv.	09 July 05	0
	3965	SPOT	Mini-can	male, 11 m	juv.	10 July 05	26
	6335	SPOT	Mini-can	female, 15	adult	15 July 05	0
	7926	SPOT	Mini-can	female, 12	juv.	15 July 05	0
	20162	SPOT	Implant	male, 12 m	juv.	17 July 05	0
	20165	SPOT	Implant	female, 9 m	juv.	15 July 05	0
	20167	SPOT	Implant	unkn., 11 m	juv.	15 July 05	200[2]
	20168	SPOT	Implant	female, 13 m	juv.	15 July 05	2
	20687	SPOT	Implant	male, 9 m	juv.	10 July 05	55

[1] Gender determined by genetic analysis (see text). Whales identified with asterisks were accompanied by calves. Bowhead whale females are thought to reach sexual maturity at 13.0-13.5 and males at 12-13 m (Koski *et al.* 1993, O'Hara *et al.* 2002).

[2] This tag continues to transmit as of 31 January 2006.

Figure 1. Map depicting placenames used in text and the known range of bowhead whales in the eastern Arctic (inset map). Star symbols in northern Foxe Basin and Cumberland Sound designate location of tagging efforts referred to in Table 1 and described in the text.

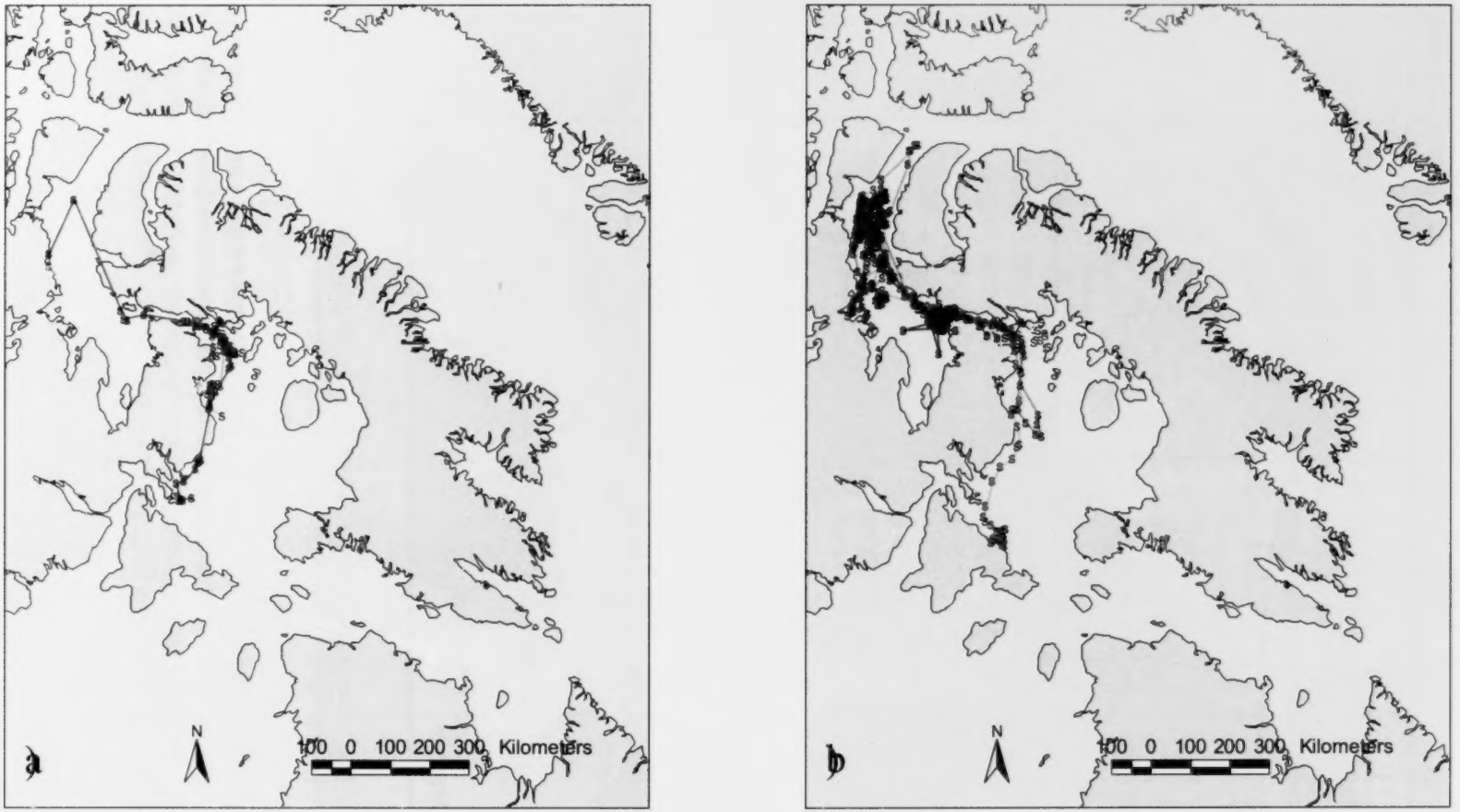

Figure 2. Maps depicting the range of movements based on satellite telemetry results for bowhead whales tagged in northern Foxe Basin in a) 2002 and b) 2003.

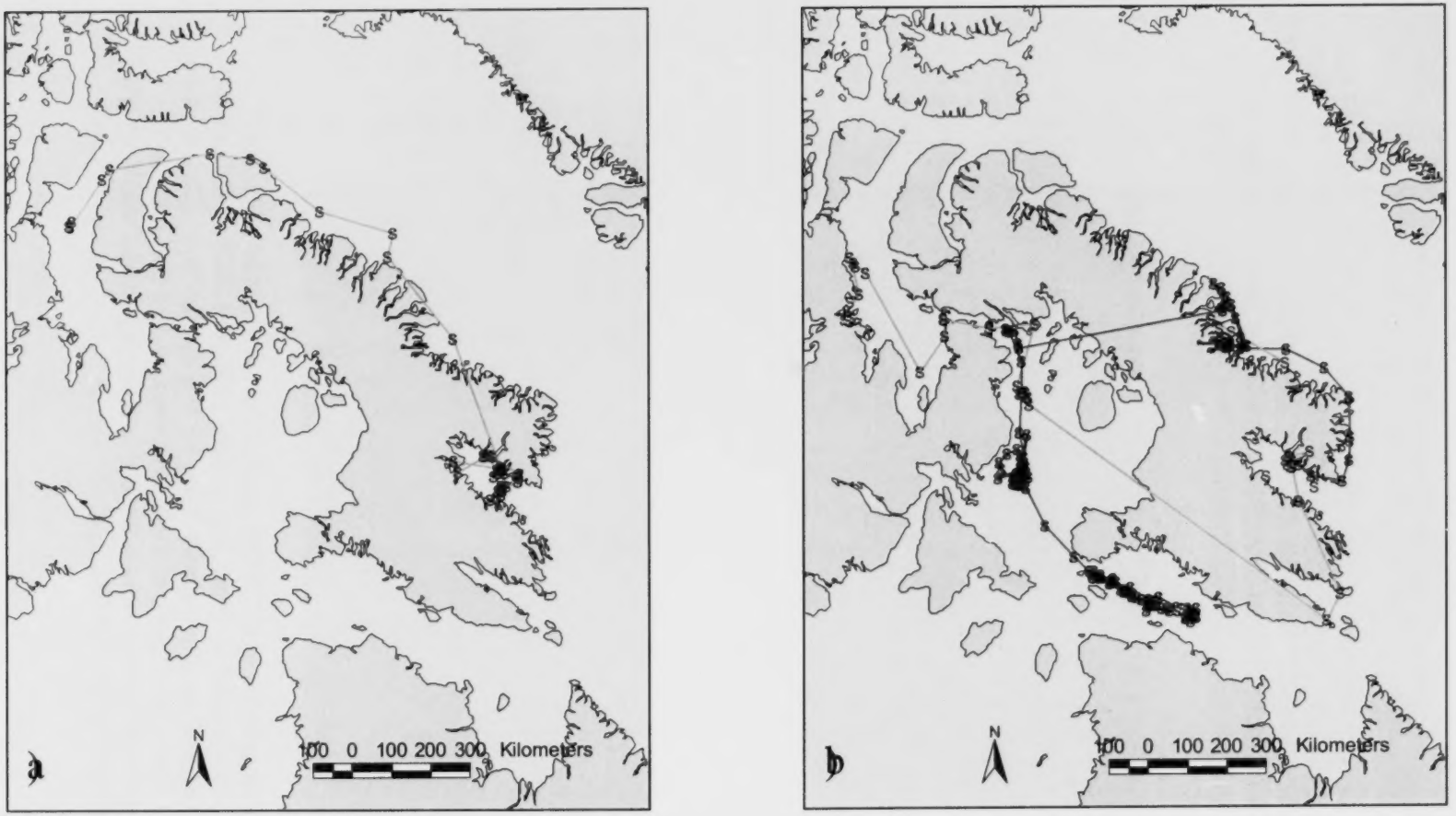

Figure 3. Maps depicting the range of movements based on satellite telemetry results for bowhead whales tagged in northern Foxe Basin in a) 2004 and b) 2005.

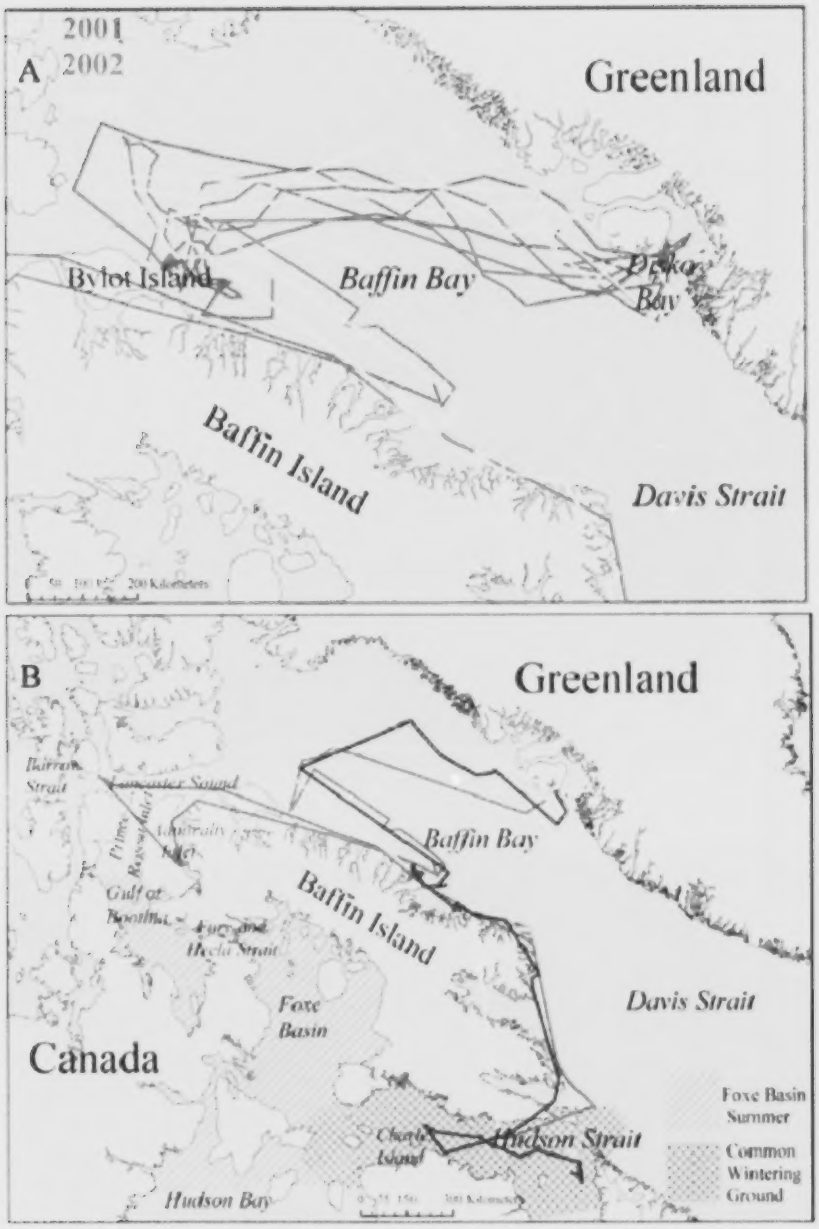

Figure 4. From Heide-Jørgensen *et al.* (2006), illustrating: A) The tracks of nine bowhead whales that were tagged in Disko Bay in May 2002 and 2003. Positions are based on daily averages of all quality classes. Data for two whales from 2001 are from Heide-Jørgensen *et al.* 2003. (B) Tracks of three bowhead whales that provided positions through mid-November (red, whale 20160) and through mid-December (blue, whale 20688-03 and yellow, whale 20696).

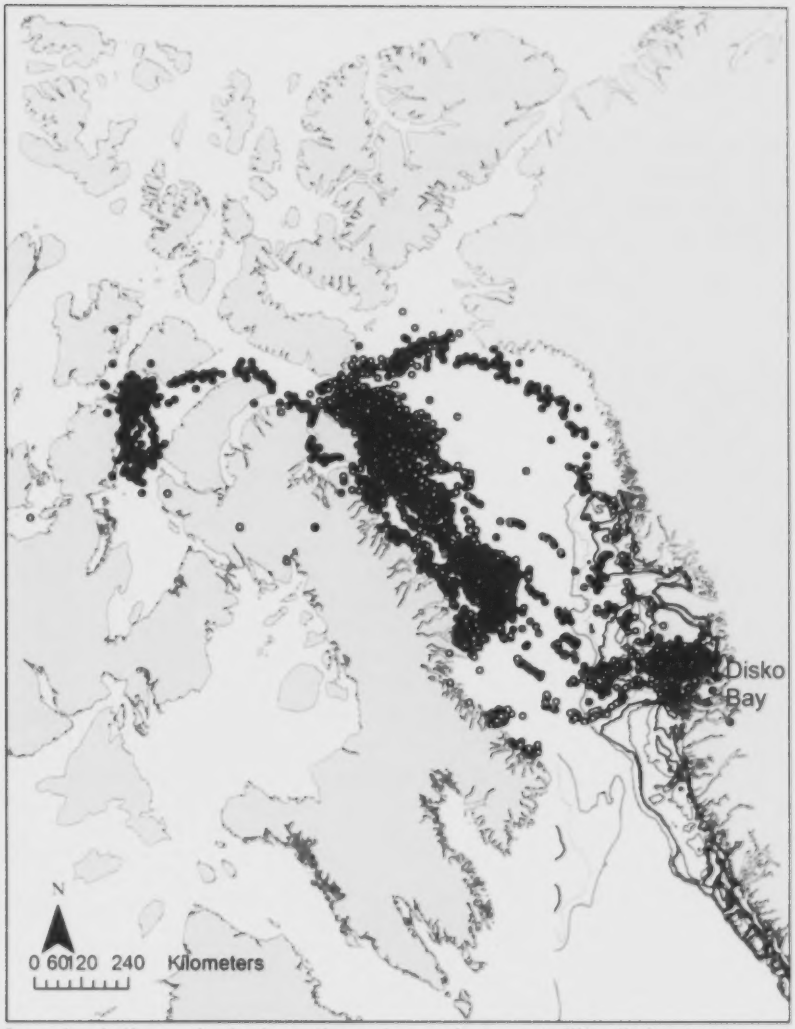

Figure 5. Map depicting whale locations based on satellite-linked telemetry results for 14 bowhead whales tagged in Disko Bay, Greenland in April 2005. Locations represent good quality data (≥ 1) for the period April to September. Unpublished data provided by Mads Peter Heide Jørgensen (Greenland Institute of Natural Resources).

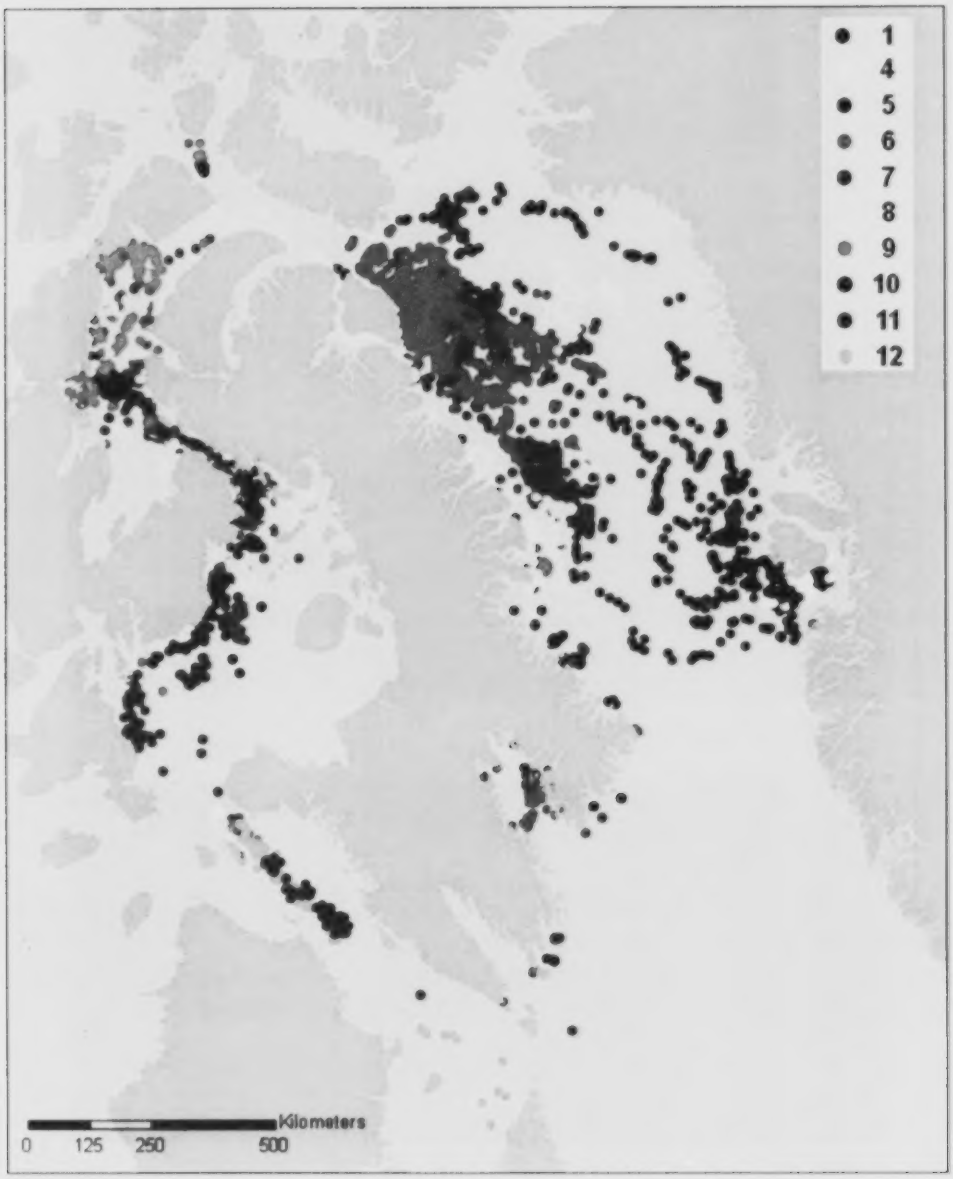

Figure 6. Map depicting seasonal distribution of bowhead whale locations based on satellite-linked telemetry results for whales tagged in Canada and west Greenland. Numbers for colour codes refer to calendar month. Unpublished data provided by Mads Peter Heide Jørgensen (Greenland Institute of Natural Resources).